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THz Waveguides: The Evolution

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Abstract- The development of waveguides is a key element in the technical maturity of the THz field. Suitably designed waveguides can provide innovative solutions for the most fundamental problems of THz energy transfer to the more advanced problems of THz spectroscopy.

This presentation will give an overview of the chronological development of THz waveguides, starting from the initial time-domain experiments to the present state-of-the-art, highlighting breakthroughs. Experimental results obtained through waveguide characterization by THz time-domain spectroscopy will be presented and compared to well-known theoretical models, looking at issues related to energy coupling, attenuation, and dispersion, as well as single and multi-mode propagation.

INTRODUCTION

The THz frequency range, located midway between microwaves and optical waves, presents a virtually unexplored region of the electromagnetic spectrum containing an abundance of technical applications and fundamental research problems. As such, THz research solutions and techniques can be found from either the field of optics or the field of microwaves, or from unique combinations of both. Along with THz investigations comes the need for enabling technologies and techniques. However, due to the developing nature of THz capabilities, commercial THz technology is minimal and one has to rely on custom fabrication. At the present time, the one-of-a-kind, laboratory THz time-domain spectroscopy (THz-TDS) system [1] capable of generating and detecting freely propagating THz pulses primarily drives the technology, enabling both fundamental and applied research.

To expand the overall range of THz capabilities, in recent years, there has been a continual effort to investigate the guided-wave propagation of THz pulses and the associated coupling between guided and freely propagating THz waves. This has led to a series of time-domain studies into the feasibility of different waveguide configurations borrowed from microwaves and optics. Experimental investigations have been carried out by incorporating the waveguides into the THz-TDS system, and analyzing their guided-wave behavior via the propagation of sub-picosecond THz pulses. The coupling of the broadband THz pulses into most of these waveguides was achieved by quasi-optics, employing hyper-hemispherical or plano-cylindrical silicon lenses. In some cases, single mode propagation was achieved despite the input spectrum extending beyond the cutoff of several waveguide modes. The waveguides that were studied included the hollow metallic circular waveguide [2,3], the hollow metallic rectangular waveguide [3], the sapphire fiber [4], the plastic ribbon waveguide [5], the air-filled parallel-plate waveguide [6,7], the plastic

photonic crystal fiber [8], the coaxial waveguide [9], the metal wire waveguide [10,11], the parallel-plate photonic waveguide [12], the metal sheet waveguide [13], and the dielectric-filled parallel-plate waveguide [14].

This presentation will give an overview of the experimental and theoretical investigations into these THz waveguides, describing their strengths and weaknesses, in terms of the propagation loss, group velocity dispersion, free-space to waveguide coupling, associated with their respective propagating modes. It will also address potential applications of these waveguides to high-speed integrated guided-wave devices, medical diagnostics, sensing, and guided-wave spectroscopy [15].

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